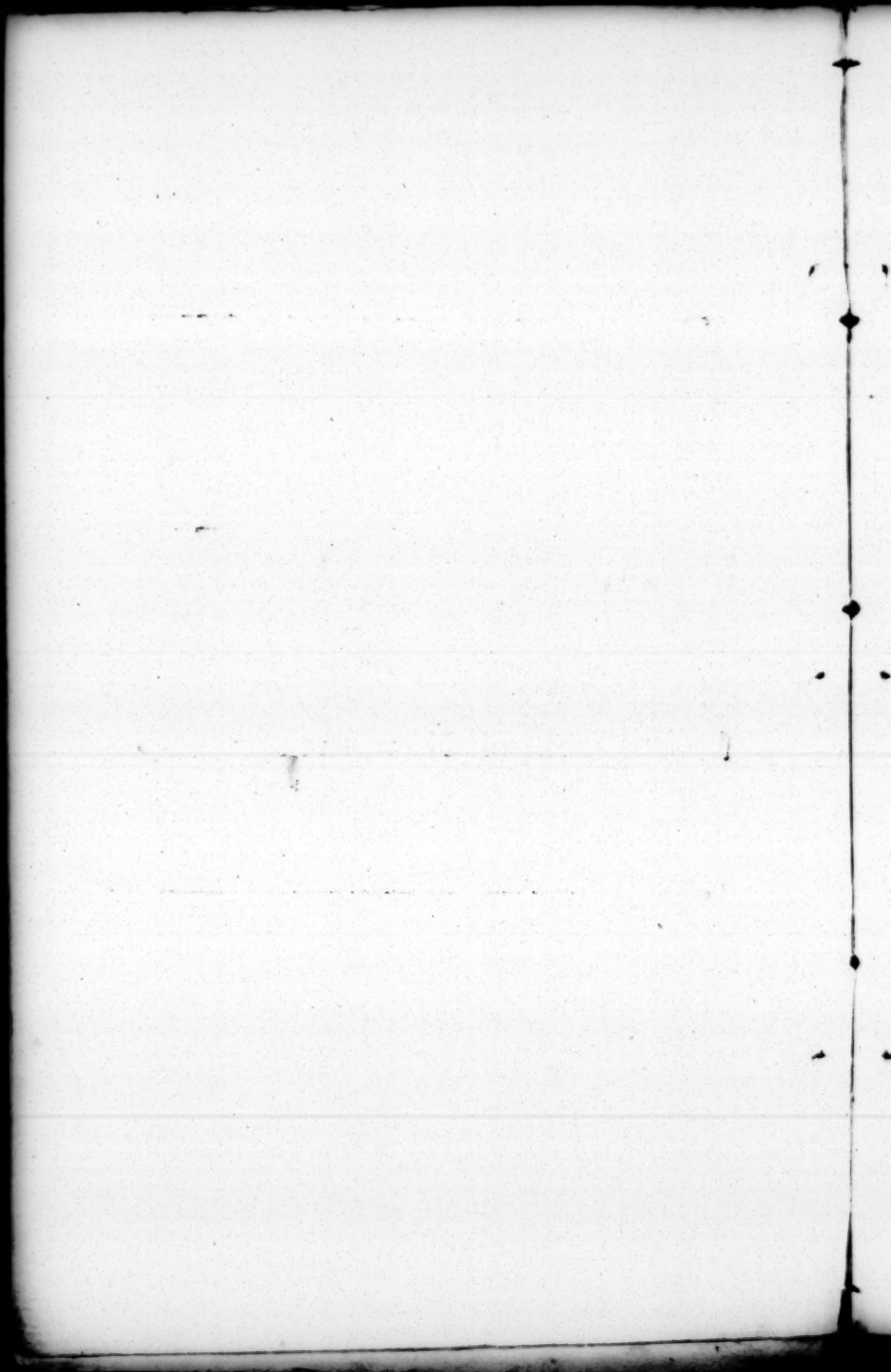


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A N  
**E S S A Y**

Towards the  
**Improvement of NAVIGATION, &c.**

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A N  
E S S A Y

Towards the  
Improvement of NAVIGATION,  
Chiefly with Respect to the  
INSTRUMENTS used at SEA.

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By W. MAITLAND.

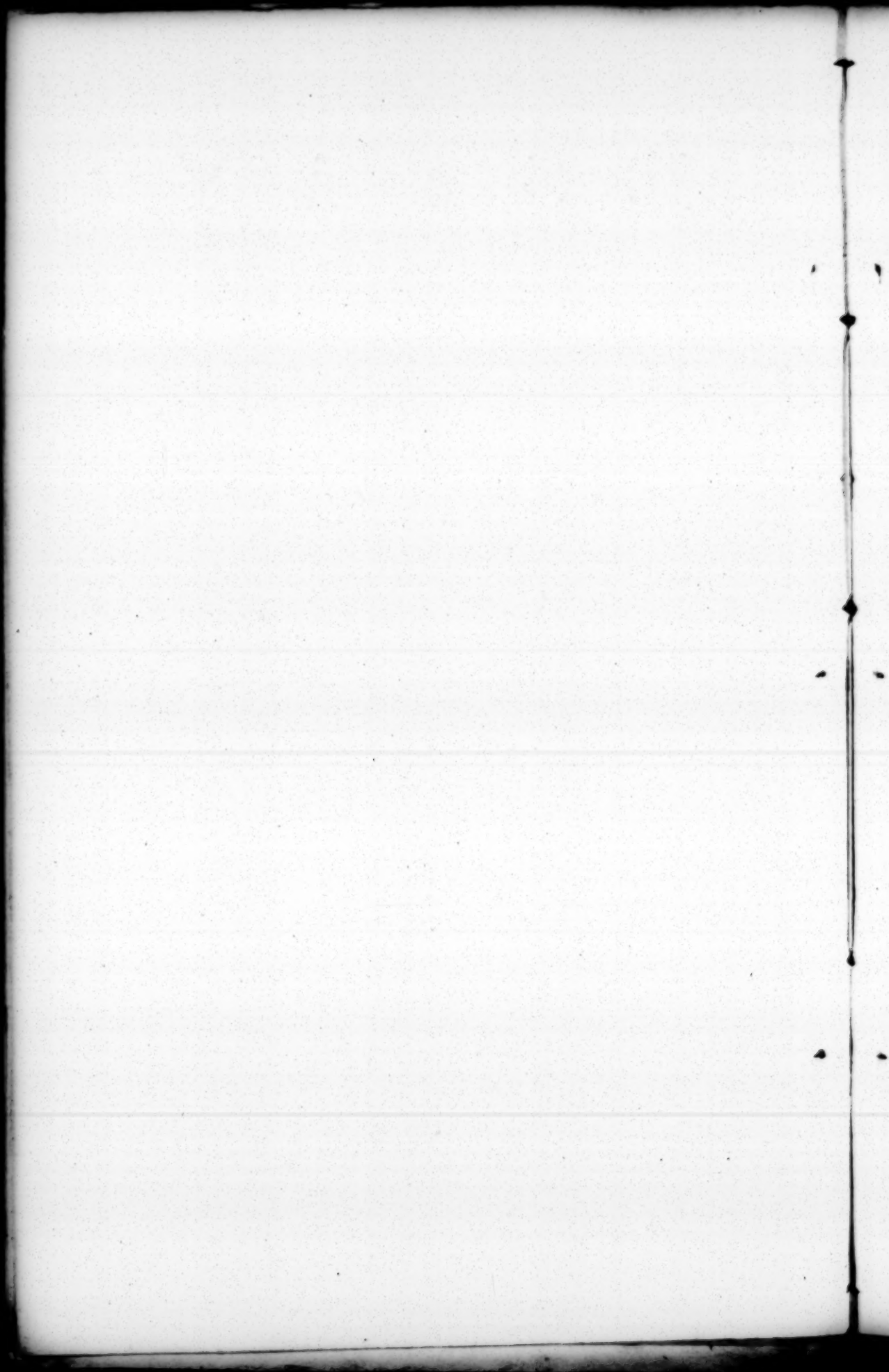
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L O N D O N:

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TO THE  
RIGHT HONOURABLE  
**The LORDS COMMISSIONERS**

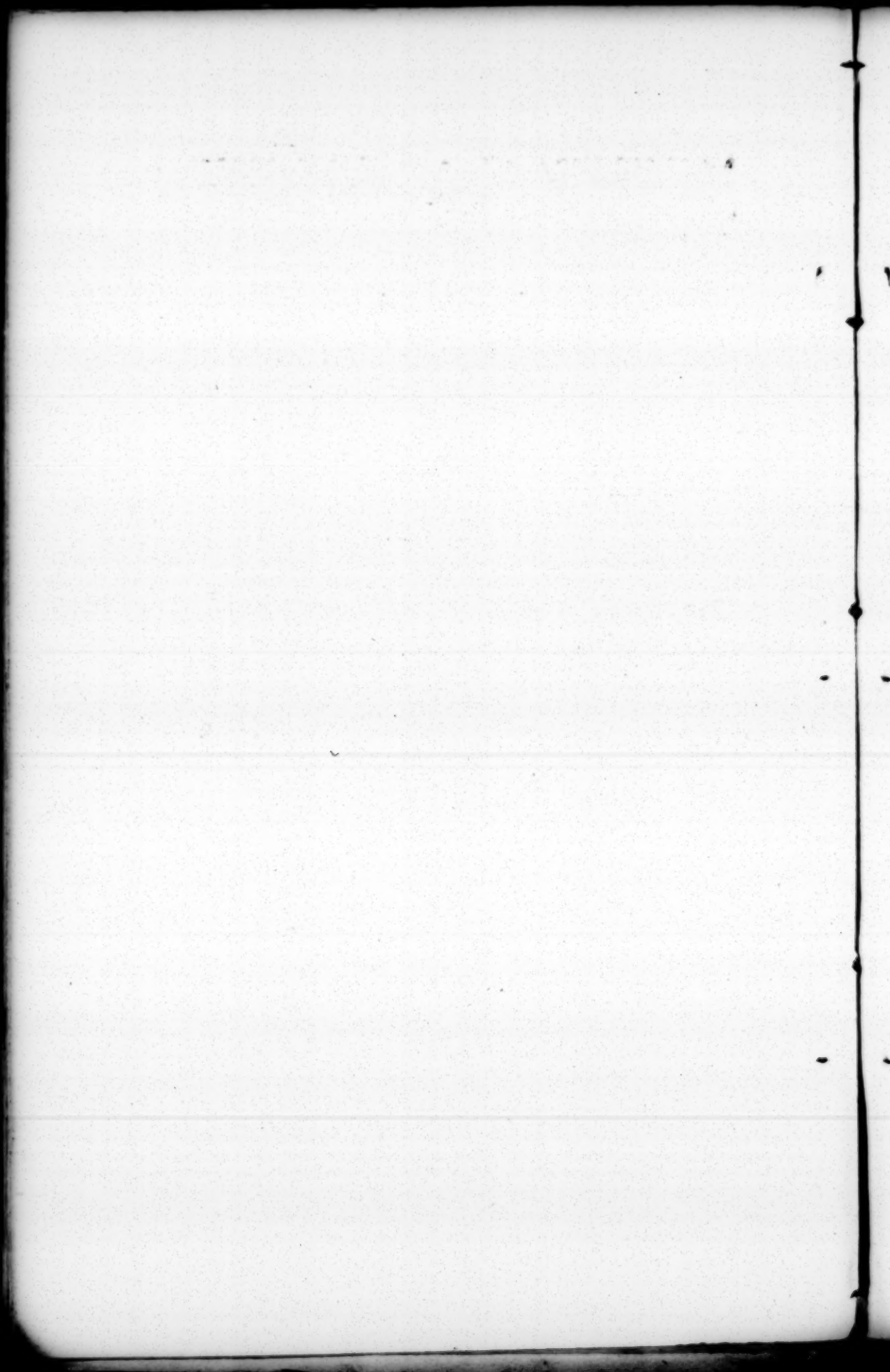
For executing the OFFICE of  
**LORD HIGH ADMIRAL**  
*of Great Britain, Ireland, &c.*

This E s s a y is, with the utmost Submission  
and Gratitude, offered by

*Your* LORDSHIPS

*most obedient Servant,*

**W. MAITLAND.**





To the HONOURABLE

Sir *PETER WARREN*,

KNIGHT of the BATH, &c.



LATTERY as it shews the basest Mind in him who offers it, so it is justly despised by every Man of Worth and good Sense; all who know You, Sir, are perswaded that Honour, Bravery, and in short, the Virtues which can render any Man happy in his own Mind, and beloved by all the Good and Wise, have in You been deservedly rewarded by Fortune's Gifts, and your King's adequate Sense of your great Merit.

To You, Sir, this first Attempt I ever made to appear as an Author,  
from

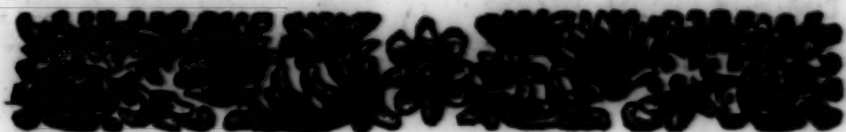
# DEDICATION.

from my Perswasion of your Capacity  
of judging well, and the Sense of my  
Obligations to You, is with equal Re-  
spect and Gratitude, addressed by

*Your most Obedient Servant,*

W. MAITLAND.





A N  
E S S A Y

Towards the  
Improvement of NAVIGATION.

**T**HE Art of Navigation is of so great Consequence to Mankind in general, that any Attempt to improve it is certainly in itself laudable : And whoever is so lucky as to succeed in an Enterprize so very useful, as he deserves the Esteem and Thanks of the Publick, will (no doubt) meet with these and other Rewards due to his Merit.

To some it may appear superfluous, for one who is but little known to the World, (and such I freely confess I am) to engage in a Subject in itself difficult, and which has been already so largely treated of by many, well known to be Men of the greatest Genius and Knowledge.

But, I take it for granted, that Navigation, notwithstanding the great Improvements already

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made

made in it, is still capable of farther; and these I shall propose in the following Essay, I believe, are intirely New, the Result of a good deal of Thought, and a great many Experiments; and as for their Worth, that must be determined by such, whose Knowledge and Candour will render them adequate and impartial Judges.

And here I must beg Leave to caution my Reader, that wherever I find Fault with any of the present Practices in the Art of Navigation, it is done, not with any ill-natured Intention; but from the Necessity there is of shewing the Defects of some of the Methods now in Use, in order to remedy them, or propose better in their stead.

To proceed then, I shall in the first Place consider the usual Methods of keeping an Account of a Ship's Way, upon the Supposition that the Instruments used to discover the Quantity, and Direction of her Motion, were free from Error: And next examine these Instruments to know what Errors they are liable to, and propose the best Means I can of lessening these Errors.

The three several Methods by which a Ship's Reckoning is kept are, Plain, Middle Latitude, and *Mercator's* (properly *Wright's*) Sailing, of which in their Order.

PLAIN SAILING, so called from the Hypothesis on which it is founded, which is, that the Earth (*i. e.* the Land and Water) forms a  
plain

plain Surface, bounded by equal and parallel straight Lines ; two of which, *viz.* the Northern and Southern Boundaries limit the greatest North and South Latitudes, and are parallel to, and at equal Distances from the Equator, which is divided into 360 equal Parts, called Degrees of Longitude ; through the extreme Points of Division of this Line, Perpendiculars drawn, till they meet the Northern and Southern Boundaries on each Side, compleat the Parallelogram ; and these last Perpendiculars from the Equator, Northwards and Southwards, being divided into 90 Degrees of Latitude each, and Parallels drawn to these thro' each Degree of Longitude, (called Meridians) and to the Equator through each Degree of Latitude, called Parallels of Latitude compleat the Plain Chart, which has the following Properties in common with a Globe, (which is known to be nearly the Figure of the Earth :) A Degree of Latitude is every where equal to a Degree of Longitude upon the Equator, as on the Globe. A straight Line drawn in any Direction that is Oblique to the Meridians, or Parallels of Latitude, which is called a Rumb, will have this Property in common with a Rumb described on the Globe, that it will make equal Angles with all the Meridians it passes through.

But then, the Meridians in this Projection are Parallel and Equidistant, which in the Globe are not so, excepting just at the Equator from whence they all conspire, and at length



meet in the Poles. Hence, if two Places of an assigned Latitude and Longitude were marked upon the Globe, and these Places laid down by their Latitude and Longitude in this Chart, their Bearing and Distance on the Chart would be very different from their real Bearing and Distance on the Globe; the Distance being greater, and the Angle the Rumb makes with the Meridians, (that is the Bearing) also greater in the Chart than on the Globe. It is true, that upon or very near the Equator, where the Meridians are either Parallel or nearly so, this Projection will agree with the Globe; but no where else, and the greater the Latitude, the greater will be the Error in the Bearing and Distance of two Places, having equal Differences of Latitude and Longitude: So that at last if we imagine two Places, each in  $89\frac{1}{2}$  Degrees of North Latitude, and their Difference of Longitude 180 Degrees; it is evident the Places will bear due North of each other, and their Distance will be just a Degree of the Meridian, or 60 Sea Miles, whereas by this Projection these Places will bear due East and West of each other, and their Distance will be nothing less than 180 Degrees of the Equator or Meridian, amounting to 10800 Sea Miles or 3600 Leagues; a monstrous Absurdity!

Plain Sailing then evidently appears to be a very erroneous Method of keeping a Ship's Way, and, I hope, none do practise it, unless at or near the Equator.



MIDDLE LATITUDE SAILING, I allow to come nearer the Truth than Plain Sailing; but it is nevertheless false, and though the Error attending it is but trifling near the Equator, it will not be found so in greater Latitudes; add to this that there is hardly any Labour saved in keeping a Reckoning by this Method, and there must undoubtedly some Pleasure arise to a Man's Mind that loves Truth, from reflecting that the Method he follows will never lead him into any sensible Error; such is that commonly called *Mercator's* Sailing, (though with great Injustice) for, in fact, it was the Invention of our worthy and ingenious Countryman Mr. *Edward Wright*, with whom this *Mercator* was Contemporary about 170 Years ago; to him Mr. *Wright* communicated his Invention, and *Mercator* basely pilfered and published it as his own: However, to do all the Justice we can to the Memory of so great a Genius, we will call it *Wright's* Projection.

WRIGHT'S SAILING. Mr. *Wright* having duly considered the gross Errors arising from sailing by the Plain Chart, set about correcting it. He saw there was a Necessity of keeping the Meridians straight, and parallel Lines, otherways the Rumbs must be Spirals, as on the Globe; the describing of which on Paper, must be at once very troublesome and inaccurate: He also discovered the want of a just Proportion in the Plain Chart, between the  
Degrees

Degrees of Latitude and those of Longitude, both being every where equal here, whereas on the Globe they are only equal at the Equator, but these of Longitude less in all its Parallels, and just in the Proportion of the Radius of any Parallel (that is the Cosine of its Distance from the Equator, or its Latitude) to the Radius of the Globe; and this Proportion of the Cosine of the Latitude of any Parallel to the Radius, is that of the Radius to the Secant of that Parallel's Latitude; therefore any Arch upon the Equator, or Meridian, (suppose) of one Degree exceeds a Degree of Longitude on the Parallel (suppose) of Sixty Degrees, in the Proportion that the Secant of Sixty Degrees exceeds the Radius; and as the Secant of that Arch is twice the Length of the Radius, so is a Degree of Latitude twice the Length of a Degree of Longitude, on that Parallel. But since in this Projection, for the Conveniency of having the Rumbs straight Lines, it was necessary to keep the Meridians Parallel, whence a Degree of Longitude on any Parallel is of the same extent as on the Equator, in order to keep up the Proportion that obtains in the Globe between a Degree of Latitude and of Longitude, at the Parallel of Sixty, which has been found as above, to be that of 2 to 1, there will be a Necessity of making the Degree of Latitude, at that Parallel, twice as long as a Degree of Longitude; and if in this Projection, the Degrees of Latitude are every where lengthened in the Proportion of the Radius, to the Secant of  
of

of the Latitude of the several Parallels, there will every where the same Proportion obtain, between the Degrees of Latitude and Longitude, that does on the Globe itself; and the Plain Chart thus corrected will be as exact as the Globe, and much more commodious for the Purposes of Navigation.

From what has been said of this valuable Projection, I presume the Principles from which the Table of Meridional Parts is computed, and thence dividing the Meridian of the Chart must easily appear. The Construction and Use of the Chart, as they are delivered at Length, by almost every Writer on Navigation, I shall here omit, my Design being in the plainest Manner I could, to shew by what Means the Plain Chart, from being a most absurd Projection of the Surface of a Globe, is by Mr. *Wright's* beautiful Correction, become the most accurate and commodious that has been, or perhaps ever will be contriv'd.

If sailing by Mr. *Wright's* Projection is the only true Method, and attended with very little (if any) more Trouble than either of the other two, which are manifestly false; it follows, that no other than his ought either to be taught or practis'd. Indeed, if it were necessary to work every single Course a Ship makes, in this manner, it would often be tedious; but there is no Occasion for that; for if the Difference of Longitude in a Day's Run is found once for all, it will be sufficiently exact. But as the Course and Distance made good for the  
Day



Day, are the Ground-Work on which this Alteration of Longitude depends; supposing the Log-Board to contain the Data necessary for finding these, I cannot help thinking, that he who lumps two, three, or more Courses together, making one of all, and lessens the Distance as his Fancy directs, depends too much on his Skill, let it be the Effect of ever so long Practice: And I am certain, that after all the Helps the best Sea Instruments afford us, a Man may find Employment enough for his Judgment to keep his Reckoning tolerably near the Truth.

There is another Thing which cannot miss being the Source of frequent Errors in Reckonings, and that is, the want of duly observing and keeping a proper Register of the Leeway a Ship makes: The Quantity of the Leeway (when a Ship makes any) is altogether as necessary to be known in order to determine the Course she makes good, as is the Point at which she Capes; and it is certainly as unreasonable to guess at the Leeway from the Sail the Ship has abroad, without setting her Wake by a Compass, as it would be to guess at the Point she Capes at, without consulting the Compass. It may be perhaps objected, that in the Night, there is no way of setting the Ship's Wake by a Compass, and therefore, it must be guessed at in the best Manner one can: But I shall propose a Way, by which it may be known then, as well as in Day-time: Thus, at some small Distance from the Ensign-Staff  
on



on either Side of it, let there be fixed a Quadrant of Wood, of about 18 Inches Radius, the Arch turned outwards, one Radius placed parallel to the Direction of the Masts, and the other will be parallel to the Beam ; and let the Plain of each Quadrant dip about 20 Degrees below the Horizon, in such manner, that when a Log or any small Piece of Wood is let go a-stern by a Log-line, till out of the Eddy of the Ship's Wake, this Line may be nearly parallel to the Plain of the Quadrant ; let the Arch of each Quadrant be divided into eight equal Parts, and Wooden Pegs fix'd in the Center, and in each Point of Division ; and each of these Parts being subdivided into four, may have smaller Pegs fix'd in their Points of Division ; by this Means each Quadrant will, by the great Pegs, be divided into Points of the Compass, and by the small Pegs, into Quarters of a Point. Suppose now, in a dark Night, the Ship makes Leeway, and I want to know how much it is, imagine the Starboard Tacks on board, I go to the Quadrant on the Starboard Side, and having veered a-stern the common Length of a Stray-line, I make a Bight in it, and put it over a Pin I suppose fix'd in the Center of the Quadrant, and feeling whether the Line bears against any of the Pegs upon the Arch ; if it does, I let it at Liberty, till it plays freely between some two of the Pegs ; then I reckon (beginning at the End of the Arch toward the Right Hand) how many Spaces between the great Pegs till you come to the Line, for so many are the Points of Leeway,

and if you have any odd smaller Spaces, so many Quarter Points. If the Larboard Tacks are on board, you go to the Quadrant on the Larboard Side, and proceed in every Respect as before, only when you count the Points of Leeway, begin at the End of the Arch toward the Left Hand. The Reason why the Plain of each Quadrant must be placed so as to shelve towards the Water, will appear if we consider that the Stray-line will be in a Direction oblique to the Horizon, supposing the Ship upon an even Keel ; besides the Allowance which must be made for her heeling to Leeward.

It is certain, that two Ships sailing in Company, which steer the same Point by the Compass, and carry like Sail, will make different Leeway ; nay, even the same Ship, in like Circumstances, with Respect to Wind, Sails, &c. if only her Trim is alter'd, will not make the same Leeway ; some again, every thing else alike, on one Tack, make more Leeway, than on the other : From which it appears highly unreasonable for any Man (let his Experience at Sea be ever so great) to trust to his Judgment only, in determining the Leeway of a Ship : I grant that in gueßing often, he may some Time or other come near the Truth, but if we allow that every Error here, really affects the Course when corrected, as much as that Error amounts to, and that we may, by an easy Experiment, (of setting the Ship's Wake by a Compass in Day-time, or in the Night, by the Method I have propos'd) ascertain the Leeway to less than  
a Quarter

Quarter of a Point, one would naturally conclude that Way ought to be practis'd, that is attended with the least Error.

I shall now proceed to examine the Log, to shew how much it may be depended on for determining the Rate of a Ship's going, and to offer another Instrument which seems better to answer that Purpose.

The Log, and manner of using it at Sea, are too well known to want any Description here: Let it suffice to mention, that from the most accurate Observations of the greatest Mathematicians, made in different Parts of the World, on purpose to determine the Length of a Degree of the Meridian, Equator, or any great Circle of the Earth, it appears to be more than 360000 *English* Feet; however, as this is a round Number, and nearly the Measure of a Degree, if we divide it by 60 (the Minutes in a Degree) the Quotient 6000 will be the Number of Feet contain'd in a Sea-Mile, and this divided by 120, quotes 50 Feet; that is, 50 Feet is the  $\frac{1}{120}$  Part of a Sea-Mile; and the  $\frac{1}{120}$  Part of an Hour being half a Minute (the Time allow'd for the Experiment) 'tis evident that if a Ship runs 50 Feet in Half a Minute, and goes on at the same Rate, she must run 120 Times 50 Feet (that is 6000 Feet, or a Sea-Mile) in 120 times Half a Minute (that is 60 Minutes, or one Hour) and on the Supposition that the Log keeps its Place in the Water, as many times 50 Feet as the Ship runs from the Log in half a

C 2

Minute;



Minute ; so many Miles in an Hour will she sail at the same Rate of going. How the Length of a Knot came to be shortened from 50 to 42 Feet, I know not, but am apt to think it was first done to keep the Reckoning a-head of the Ship ; if so, it was erring too much on the safe Side, in a Voyage of 700 Leagues to look out for Land which was still 112 Leagues distant : But having found by Experience, that this Odds was too great, the Time for the Experiment was by Degrees lessened from Half a Minute, or (30 Seconds) to about 27 Seconds, which is nearly the Time in the same Proportion to 42 Feet (the usual Length of the Knot) that Half a Minute bears to 50 Feet. If in Place, however, of shortening the Knot, the Time had been lengthened, it would have answer'd the cautious Purpose of keeping the Reckoning a-head of the Ship, with this Advantage besides, that the Log would have been somewhat less liable to Error.

I shall now go on to shew that the Log is a very inaccurate Instrument for determining a Ship's Rate of sailing, which I presume will appear from the following Considerations :

Suppose a Ship sailing at the Rate of 10 Knots an Hour, and that the Log is hove ; let 26 Seconds be called the just proportional Measure of Time, to the Knot of 42 Feet ; suppose then the Glass takes only 25 Seconds in running, and that the Man who holds the Glass, turns it one Second too late, and calls Stop, one Second too soon ; in that case it is evident, the  
Time



Time which is taken for 26 Seconds is no more than 23 ; and though she really goes at the Rate of 10 Knots, yet by the Log she goes not quite 9 Knots : Again, let the Glas be supposed to run 27 Seconds, and after being turned precisely, suppose him who holds it to call Stop one Second too late ; in this case what is look'd upon as 26 Seconds is really 28, and the Ship seems by the Log to go almost 11 Knots, when she really goes no more than 10. Hence 'tis plain, that from a small Error in the Glas, and a little want of Care in him who turns it, the Ship may appear by the Log, to go one Mile *per* Hour, more or less, than she really does ; which, if she goes at the same Rate for twenty-four Hours, is likely to produce an Error of so many Miles.

That a greater Error than I have suppos'd, often happens in the Glas, is consistent with my Experience, and I dare say that of many others ; nor will the Error I have suppos'd in the Management of it, appear extravagant to any who has often seen and strictly observed the Manner of heaving the Log.

A new Log-line after being stretch'd, and the Knots divided from the usual Measure, for some Time after it is used, will shrink a good deal ; and when it has been long used, will stretch again beyond its first Length : So that unless great Care is taken oftner to adjust the Length of the Knots, than I could ever observe used at Sea, considerable Errors must ensue.

But

But supposing the Glas an exact Measure of the Time, and managed without Error, and the Knots to be of a just Length; it is requisite that the Log should remain in the same Place in the Water; for if it follows the Ship with a slower Motion, the Result of the Experiment is only the Difference of the Motion of the Ship and of the Log, which will be less than the Ship's Rate of going; and if the Friction of the Reel has no Effect in making the Log follow the Ship (which I can hardly agree to) it is certain, that when the Ship goes before a brisk Gale of Wind, the Log must be drove towards the Ship with some slow Motion: Supposing, again, that it blows a brisk Gale, and the Ship upon a Wind; it is plain that in this Case the Log will be drove from the Ship with a slow Motion. In the first Case, the Log will give less than the real Motion of the Ship; and in the last, the Ship will seem to make more Way than she really does. Upon the Whole, if the Glas is allowed to err but a little, if he that turns it may be out a Second or two, if the Knots are a little longer or shorter than they ought, and if the Log shifts its Place in the Water (all which I think may be presumed as highly probable or certain:) These Errors though each of them be small, yet, when they all conspire together, must greatly magnify or lessen a Ship's real Motion: If indeed they happen at any Time to have equal and contrary Effects (which must very seldom

seldom be expected) then, and then only will the Log ascertain the true Rate of a Ship's going: And now, that I think it must be evident, that the Log is an Instrument very little to be depended on; I shall describe one which I take to be liable to much less Error.

Imagine a Ball of Metal (suppose Brass) of a known Diameter, admit of three Inches; the Metal of such a Thickness, that the Ball will be nearly of the same Weight with its Bulk of Sea-Water; that is, of the same specific Weight with it: Suppose there is a Hole of about half an Inch Diameter cut in it, and a Piece made to screw into this Hole, so that when screwed home, its outer Surface may be of the like Convexity, with that of any other equal and like Part of the Surface of the Ball; and in the Middle of this Piece let a small Hole be drilled, big enough to receive a common-sized Log-line, which imagine passed through the Hole (the Piece being unscrewed) and fastened (by a Knot made on the End of the Line) on the concave Side, and then the Piece screwed home: The Line thus fastened to the Ball may be 15 or 20 Fathoms long.

Suppose now, in a Ship going at a small Rate of perhaps 3 Knots an Hour, this Ball is hove from the Poop, and let veer a-stern the whole Length of the Line, when brought up it will be in Tow of the Ship, and Part of the Ball will be above the Surface of the Water, while it meets with a certain Resistance in  
passing



passing through the Water ; suppose the Ball brought on Board, the Piece unscrewed, and a small Quantity of Bird-shot being put into it, the Piece again screwed home, and the Ball veered a-stern as before ; if the Specific Weight of the Ball is now enough encreased, it will be altogether under Water, and the Resistance it will meet with in passing through the Water, will be greater than formerly, the Ship going at the same Rate.

Let the Ship now be supposed to go at the Rate of 10 Knots, and the Ball enough loaded to keep under Water, and veered a-stern, it will meet with much more Resistance in passing through the Water, than before.

In general, the Resistance the Ball meets with in passing through the Water (so it is enough loaded to keep under Water) will be greater, as the Ship's Rate of going is encreased ; and less, as that is diminished ; and the same always, when the Ship goes at the same Rate : Whence it follows, that if we can Measure the Quantity of this Resistance at the several Rates of a Ship's going, we shall be able thence to determine the present Rate a Ship goes at. The most convenient Way of measuring this Resistance, seems to be, by Means of a Spring, which will from every different Pull of the Line, suffer a new Degree of Tension ; and any one Degree of this Tension may easily be compared to its equal known Weight, by suspending such a Weight at the Spring, as will reduce it to the given Degree of Tension.

Hence



Hence, the several Weights in Pounds, Ounces, &c. which are equal to the several Strains of the Spring, corresponding to the various Resistances the Ball meets with at the several Rates of a Ship's going, being known; it is easy to see that any Number of Springs, (let their Degrees of Elasticity be ever so different) may be with certainty adjusted for this Purpose. It is true, that the Accuracy of this Instrument must depend upon the Care that is used in being well assured of the several Rates of a Ship's going, which, I think, may be very nearly known, if a Ship is made to Sail at a good Number of different Rates, between two Points of Lands, whose Distance is well determined, and a good Watch used to measure the Time in which the Ship, with different and uniform Velocities runs the same known Distance.

I would not be thought to mean that this Contrivance, though executed and applied in the Manner I have proposed, will precisely discover the Rate a Ship goes at; but it bids fair to assign it much nearer the Truth than the Log, and if upon Trial it is found so to do, ought certainly to be used in Place of it: From the Trials I have made with it, it appears to be much preferable to the Log; however, as it is very common for People to be prejudiced in Favour of their own Inventions, I am willing that from impartial Trials of it and the Log, it may be determined which best answers the Purpose for which both are intended. I know

it will be objected, that this Ball continually in Tow of the Ship, will in some Measure lessen her Way; I grant it may a little slacken her Motion; but, if it is hove once in a Quarter of an Hour, this Effect will almost vanish; and the four several Rates of going in the Hour (if they are different) being sum'd, and one fourth of their Sum took for the Mean, will approach pretty near the Truth, and may be mark'd in the Log-board as such.

It may perhaps also be objected, that the Quantity of Bird-shot necessary to keep the Ball under Water, as it must be different to every new Rate of Sailing, is not easily to be known; in answer to this, I believe, there is hardly a Seaman who cannot guess at what Rate a Ship goes, within perhaps a Knot or thereabout; and if he puts what Quantity would keep the Ball under Water, supposing her to go a Knot more, (and this Experience will discover) it will scarce make any Odds.

Thus having given the Construction and Use of the best Instrument, I could think of, for measuring a Ship's Way, I have little more to add on this Subject; only a Hint which perhaps may by some ingenious Mind be improved to bring this material Part of practical Navigation nearer to Perfection.

It seems evident, that what Effects are produced by great or swift Motions, ought to flow from less or slower Motions in a less Degree; we observe that a Projectile thrown in a Direction not contrary to that of Gravity (suppose  
it

it horizontal) describes a kind of Curve; in the Progress of the Body in this Curve, it is plain, that as the projectile Force by degrees loses its Effect, the Force of Gravity by like degrees encreases its Action on the Body, till at length the former becoming extremely small or nothing; the latter recovers all its Effect, and the Body is acted upon by the Force of Gravity alone. One would be apt to conclude from this, that the absolute Gravity of a Ship, in her progressive Motion, should be less than when at Rest; and that the greater this progressive Motion is supposed to be, her absolute Gravity should be the more diminished.

If, I say, the Action of Gravity upon a Body moved in a horizontal Direction is less, and farther diminished as this Motion is encreased; and if any practical Method can be devised, to measure these several Diminutions of the Force of Gravity; we may then know when a Ship's Motion is affected by a Current, and how much that Effect is; which are things as necessary as difficult to be known, by any Methods now in Use. I am of Opinion, that if a Ball (of Brass suppose) were to act by its Gravity on a Spring made of Steel-wire, in form of a Screw, and the Pressure of the Ball nearly such, that a Line drawn from its Center, perpendicular to the Horizon, might be the Axis of the Spring (supposing it a Cylinder) and such a Pressure of the Ball might be nearly had in a Ship under Way, by hanging the whole as a Compass is, with a proper Weight to keep



it as ready as possible: If, I say, the Diminution of Gravity from the progressive Motion of a Ship is sensible; the Axis of this Spring thus pressed by the Ball, will be shorter, when the Ship is at Rest, than when under Way: Or, (which is the same Thing differently expressed) the Ball will be nearer to the other End of the Spring when the Ship is at Rest, than when she is under Sail, and this Distance will be greater as the Rate of her going encreases.

I shall just mention another Thing, which seems to be the Effect of the progressive Motion of a Ship, and that is, that the Surface of Water in a Bowl or other Vessel on board a Ship under Sail, deviates more from an horizontal Situation, than the Rowing of a Ship would appear to cause it; I mean in such sort, that a Line coinciding with the Surface of the Water, and parallel to the Course made good by the Ship, will be more inclined to the Horizon, than any other Line of a different Direction, and that also coincides with the Surface of the Water; if this Deviation I have described, is found on Trials to be sensible, and to encrease with the Rate of a Ship's going; it might (one would think) be improved to measure the Rate of her going, and the Course she makes good, even when affected with both Leeway, and a Current running under Foot. It is probable that Quicksilver may be a Fluid more proper than Water, for making such Trials, on account of its much greater specific Weight

Weight, than that of Water, or indeed any other Fluid.

I now proceed to consider the Compass, and endeavour to rectify some things I take to be amiss in its Construction and Use.

Not only the Person to whom the Honour of so glorious an Invention is due, but even the Country is uncertain; the *Chinese* claim it as theirs; but the *Portuguese* of all the European Nations are said to have been the first, who by Means of the Compass, ventured to plow the wide and pathless Ocean, and it seems they had no better Method than swimming the Needle on a Piece of Cork in a Bowl of Water; but finding that way of using it to be inconvenient and inaccurate, the Contrivance of hanging it by a Cupola upon a Brass Point was justly preferred; and the Box that held the Card and Needle thus suspended, was in such manner hung by Means of a double Axis, as that notwithstanding the Heel or Rowling of the Ship, the Card is nearly kept horizontal.

Whatever is the Cause to which the wonderful Effects of the magnetic Needle ought to be ascribed; we find the Force which reduces it to the magnetic Meridian, and keeps it nearly so, is but small; and if there is any considerable Friction between the Cupola and the Point on which it turns, it will either quite overcome this Force, or greatly lessen it: But supposing two Cards, having Needles of equal magnetic Force, to be hung on Points equally blunt;

blunt; if one of these Cards weighs twice as much as the other, the Friction of the Heavier, will certainly be greater, as the Pressure is more, and seeing the Force which must (at least ought to) overcome that Friction is the same to both, it is plain the lighter Card may have its Needle brought to the magnetic Meridian, while the heavier Card cannot. Hence then (every thing else alike) the lighter a Card is, and the finer the Point on which it turns, the Friction will be the less, and the same magnetic Force will with more freedom act upon the Needle, and sooner bring it to its Meridian.

If the Pin that supports the Cupola, and the Cupola itself, are both made of Brass, the Point will soon wear blunt, and be apt to work a small Hole in the Cupola, which being fitted to the Size of the Point that form'd it, will render the Friction much greater than would happen from the Bluntness of the Point only; therefore it is requisite, that the Pin should be made of harder Stuff than Brass, and the Cupola ought to be of still harder Stuff than the Pin; if in place of Brass, the Pin is made of good Steel, somewhat harden'd, and the Cupola of sound Agat, and if the Pin has been brought to a fine Point, the Friction must in a long Time be very small, especially as the Card and Needle ought to be as light as they well can be made: It may be perhaps alledged, that if the Needle is very light in Proportion to its Length, it cannot have Magnetism so strongly communicated to it, as it might, if made more substantial



stantial; but granting that a heavier Needle does receive some more Magnetism from the Stone, yet if its greater Weight increases the Friction more than this additional Magnetism has Power to overcome (and I believe Experiment will shew it does) in that case there is no Advantage gain'd by making the Needle heavier, but the Friction really left greater in Proportion to the small Force which must overcome it.

From a great Number of accurate Experiments made by the ingenious Mr. *George Graham*, Watchmaker, in *Fleet-street*, and from some of which, a daily Variation in the Needle appeared, amounting to about half a Degree; from many Trials, I say, he was satisfied that the light Needles are the best, and also that about four Inches and a Half is the best Length they can be made of: And, as I question whether the World can produce his equal, considered as a Mathematician, and a curious and nice Artist, we may safely depend on the Result of his Experiments.

We conclude then, that a light Needle about four Inches and a Half long, with an Agate Cupola, and turning on a fine Steel Point is the best; and that we may still have the Point fine, it seems requisite to carry several of them to Sea, so well fitted, that any one when suspected to be blunted, may be readily unscrew'd and another put in its place; and for this Purpose, the Box in which the Card plays, ought to be so made as to be readily opened, and shut quite

quite close that no Wind can come at the Card to disturb it; nor ought two Compasses ever to be placed so near as to affect each other, nor so near any Iron as to be attracted by it.

Some Years ago I contrived a Method of hanging the Compass, which I take to be better than that now in use; I shew'd one of them executed by my Direction, to the Right Honourable the Board of Admiralty, which they approv'd of; and having tried one of them in two Voyages since, I find it to keep much steadier, and is less affected with the Ship's Motion, than these hung in the common Way. Whoever chuses to see one of them, may, by calling at Mr. *Liford's*, a Mathematical Instrument-maker, near the New Church in the *Strand*.

In bad Weather at Sea, it is common to steer by what is called a Foul Weather Compass, that is, whose Card turning on a blunt Point cannot be supposed readily to come to its Meridian; what could introduce this absurd Custom I cannot imagine; but one would reasonably conclude, that when the Steerage of a Ship is most difficult, there were then the most need of a good Compass, which will shew truly every Yaw the Ship takes, and much better inform the Men at the Helm, when, and how much they ought to check her, in order to bring her near her Course.

I should be sorry if the Freedom I take in finding Fault with some Sea Instruments, now in use, and the more than possible degree of Accuracy,

Accuracy, which many are apt to expect from them, should give Disgust ; but sure I am, that whoever sets out on my Design (which was originally to take Notice of such Errors as might be expected from their Use, and to propose the best Means I could to diminish these Errors) will find himself under the like Necessity with me to engage in the unpleasing Task of finding Fault ; and there seems Reason to hope, that when a Man's Aim is the Improvement of so useful an Art as Navigation, he will be indulged in a Freedom so necessary to, and closely connected with his Purpose.

Of all the Instruments now commonly used at Sea, I do not know one from its Construction so clumsy, or in the Use of which People are more imposed on, than that which goes by the Name of the Azimuth Compass : By it, 'tis generally imagined, that the Sun's Magnetic Amplitude, or even Azimuth, may be found at Sea, to the Preciseness of five Minutes, and consequently the Variation of the Needle to the same Pitch of Accuracy. I shall not need to describe this Instrument, as a great many Trading Ships, and all His Majesty's Ships carry it to Sea ; let it suffice to observe, with respect to its Construction, that it is a very unweildy Instrument, enough for two Men to lug upon Deck ; that whereas it requires a great Weight to keep the Compass-Box tolerably steady, it has one, much too small, which never can answer that Purpose ; that the Card



in it being eight Inches Diameter, is much too large, and too heavy, to conform itself to the Magnetic Meridian with that Briskness it ought; and that the Luggage of a heavy Index, moving on a much heavier Brass Circle, is altogether unnecessary, and can only serve by the Divisions being carried to the Exactness of five Minutes, to amuse People (who have not enough considered the Instrument) with the Fancy, that such Preciseness it to be expected from it; which I shall shew it is impossible to come at, even by an Instrument much better adapted for its Purpose. This will be very evident, if we recollect, that (from Mr. *Graham's* Experiments, we may be well assured) the Needle and consequently the Card alters its Direction at different Times of the same Day, and in the same Place, to the amount of Half a Degree; admit then, that the Card is not in the least affected by the Motion of the Ship, and that there is no Friction at its Center, yet will the Observation (however accurate otherways) be uncertain as to the Half Degree just mention'd, unless we know which Way to allow for it: This, I presume, will shew the Uselessness of a Circle, divided to every five Minutes; but if to this we add the Effects of a Ship's Rolling, of her Yawing, and of the Friction at the Center of the Card, I am perswaded a Man must be very careful, if he determines the Sun's Amplitude, and especially his Azimuth, to a Degree and a Half,

Half, even with a much better Instrument than this.

There is no such thing as Preciseness to be expected from any Mathematical Sea Instrument whatever, as most of them are liable to Error from the Motion of the Ship; it is well if we can come somewhat near the Truth, and these Instruments are certainly the best, by the Help of which, our Conclusions are attended with the least Error.

The Quantity, and Kind, of the Needle's Variation are (no doubt) of great Importance, and without the knowing of which, it is impossible to determine any one single Course a Ship makes good; the Observation of the Sun's Amplitude at his rising or setting, as both it, and the Computation from it, are more Simple than these of an Azimuth, ought certainly to be preferred when it can be had: But when an Amplitude cannot be observed; by the following Method, one may come as near the Variation, as by the Azimuth, the Computation of which is to many very tiresome.

I would chuse a Brass Compass Box that was well hung, with a sufficient Weight to keep it as steady as possible, and in place of a Card, would use a neat light Needle, playing freely on a fine Steel Point; a Diameter being drawn in the Bottom of the Box, imagine a Circle describ'd from the Center, with a Radius of about two Inches and a Quarter, which I suppose Half the Length of the Needle, and this Circle divided

into Degrees, which let be number'd either Way from each End of the Diameter ; let two Brass Sights be fitted, one at each end of the Diameter, so that the longer Sight having a Vertical Thread or Wire fix'd in it, and the other a small Hole to look through ; the Plain supposed to be erected perpendicular to the Bottom of the Box, and coinciding with the Diameter, may also coincide with the Wire in the longer, and with the small Hole in the shorter Sight ; the longer Sight may be about the Length of the Diameter of the Box, to take in any Object whose Altitude does not exceed 45 Degrees. Imagine now, that while another is with a good Quadrant, observing the Sun's Altitude, if it is less than 45 Degrees before Noon ; I observe his Bearing to be 50 Degrees to the Eastward of the South Point of the Needle : In the Afternoon, let the same Person continue to observe, till the Sun has fallen so low as to have the same Altitude as when he observed in the Forenoon, and let his Bearing then be observed, (imagine) 70 Degrees West from the same South Point of the Needle ; if we add these two Arches of 50 and 70 Degrees, the Sum is 120, the Half of which, *viz.* 60, is the Number of Degrees the Sun would have bore from the South Point of the Needle, Eastward in the Forenoon, and Westward in the Afternoon, if the Needle had no Variation ; but as the South End of the Needle pointed 10 Degrees to the Eastward of this 60 Degrees, and consequently, the



the North End of it, 10 Degrees to the Westward of the opposite Point ; the Variation plainly appears to be 10 Degrees Westerly. From this Example, I apprehend, the Advantages of the Instrument I have been describing, and of the Method I have proposed of finding the Variation of the Needle at Sea, by Means of it, will be evident ; for granting that an Error amounting to two Degrees, were committed in observing or estimating the Point of Bearing, it is certain, that in the Variation thus found, the Error would be lessened to one Degree : And in general, this Instrument must from its Nature and Construction admit of much more Accuracy in observing the Point of Bearing of any Object, than the Azimuth-Compass ; and I think indeed, must be preferable to any Compass whatever, that has its Needle loaded with a Card. In the Example I have given of finding the Variation, I have not taken Notice of the Alteration of the Sun's Declination, and the new Latitude the Ship may have arrived in, during the Time between the Observation before Noon, and that made after Noon ; but both of these Alterations may be easily had from the Log-board, and the Effect they may have in making the Sun's equal Altitude in the Afternoon, happen a little sooner or later than it would have done, had the Ship been still in the same Place ; I say, this Effect of the Ship's changing her Place, may be with sufficient Accuracy allow'd for. It seems almost needless  
to

to observe, that if the Needle is not quite settled in its Meridian, in Time of Observation, then the Middle of the Arch intercepted between the extreme Points of its Vibrations or Swings, must be took for that, at which it would settle, if it were not disturbed. If several Altitudes are taken in the Forenoon with the corresponding Points of Bearing, and in the Afternoon the Points of Bearing found when the Sun has fallen to the same Altitudes; these Observations will be a Check upon each other, for if the Middle of every two Bearings corresponding to the same Altitude, falls upon the same Degree in the Compass-Box, it may be concluded that the Observations have been good, and the Variation thence found may be depended on; but if the Middle of the Bearings falls upon different Degrees upon the Limb, some Error must have been committed in observing either with the Quadrant or the Needle, and the Variation not turning out the same from each Observation, cannot be truly assign'd; although if this Difference is but small, the Observations have been pretty accurate, and the mean Variation thence found will be near the Truth.

Another Advantage may attend making several Observations, at the Distance (perhaps) of Half an Hour from each other; that in the Afternoon, if it should be overcast so, that we cannot observe when the Sun has fallen to one Altitude, it may be clear enough, by the Time he has fallen to some other.

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Some People may think they can with greater Ease, and equal Certainty, determine the Variation from an Amplitude or Azimuth ; I must confess I am of a different Opinion ; however, if in their Observations they will make use of such a Needle as I have described, in place of that almost useless Instrument the Azimuth-Compass, I am perswaded their Conclusions will approach a great deal nearer the Truth.

If this Needle were really no better to observe with, than the Azimuth-Compass ; yet, if we consider that the whole Instrument when neatly finished, is much handier than, and not more than the third Part of the Price of an Azimuth-Compass, it certainly ought to be preferred : And as it is probable that this Instrument, and others proposed and described in this Essay, may one Time or other come to be generally used ; I hereby give warning, that none do presume to claim the Invention of, or to make or sell all or any of them, without having my written License for that Purpose.

I come now to examine the Instruments commonly used for finding the Latitude a Ship is in at Sea.

*Davis's* Quadrant, as it is in almost every Seaman's Hands, needs no Description ; but I find that most People by it expects to arrive at a Degree of Accuracy, altogether inconsistent with the Nature and Construction of this Instrument ; to me it is evident from great Numbers



bers of Observations I have made, and been present when made by others with it, that even when there is a good Horizon, a bright Sun, the Ship not rolling much, and every thing, in short, favourable for the Observation, the Latitude cannot be determined by this Instrument, nearer than to ten or a dozen Minutes: When, I say, there have been a good many observing at once on board the same Ship, with *Davis's* Quadrant, I have generally found the Latitudes computed from the Sun's greatest and least observed Zenith-Distance, to differ 10, 12 and sometimes 15 Minutes, and which of them was nearest the Truth, could not easily unless from a better Instrument be determined.

*Hadley's* Quadrant of all others that have hitherto appeared, is undoubtedly the best Instrument for finding the Latitude at Sea, when there is a clear Sky, and well defined Horizon; for one may depend upon an Observation carefully made with this Instrument (if well adjusted) even to one or two Minutes; which is but a small Error, and not more than a sixth Part of what we may expect in using *Davis's* Quadrant. But then there ought to be great Care taken that the Glasses in *Hadley's* Quadrant, are of the same uniform Thickness, and the Surfaces of them quite flat, as well as that they are justly placed, and that the Divisions are neat and accurate.

Some

Some Years ago Mr. *Bird*, Instrument-maker, at the Sea-Quadrant in the *Strand*, contrived and executed an Octant, differing from *Hadley's*, in that it is held (otherways than his) very firmly against the Observer's Shoulder, and gives the Images of the Sun and Horizon by a single Reflection, from two Glasses placed at the Center, one of which is fixed, and the other carried along with the Index : The Instrument is elegantly contrived, and executed by him with the utmost Neatness and Accuracy ; and from many comparative Trials with it and *Hadley's*, I am satisfied it is not less exact though cheaper.

While I was on the North American Coast, in one of his Majesty's Ships, under the Command of the Honourable Sir *Peter Warren*, we had frequent thick Fogs, which depriving us of a Sight of the Horizon, rendered our Quadrants of no use to us in determining our Latitude, though the Sun's Body might often be seen about Noon ; and as we were obliged to trust to our Latitude by Account, for several Days together, and in that hardly any two Persons agreeing, we were left in the utmost Uncertainty, and were at length got in shoal rocky Soundings, and sometimes not more than five Fathom Water ; there was not much Wind, and the Honourable Person, just mention'd, foreseeing Danger, ordered an Anchor to be dropt, which brought us up ; as the Ship had then but little Motion, and the Sun's Disk faintly appeared,

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Sir

Sir *Peter* having desired me to make the best Guess I could to fix our Latitude, even to half a Degree, if it could be had no nearer; accordingly I tried (by measuring the Angle of Reflexion from the Surface of a Vessel of Water, placed for that Purpose) to assign the Zenith Distance of the Sun, and thence deduced the Latitude much nearer the Truth than I could have expected: The Latitude I thus found, being nearly that of the Seal Islands, (a Parcel of small rocky Islands lying off *Cape Sable*) we concluded we were got near them, and by Sir *Peter's* Order, rode at single Anchor till next Morning, when about ten o'Clock, the Fog beginning to clear up, we were fully convinced of the Danger we had justly apprehended; for we saw the Islands round us, and the farthest at no great Distance: As it continued to clear up, the Horizon, as well as the Sun, appeared time enough for every one to observe for the Latitude, and it turned out nearly the same that is given these Islands in the Books of Navigation, and (as it happened) not more than 6 Minutes different from such an Observation as I was able to make in the Fog.

After being so sensibly convinced of the great Usefulness of a well contrived Instrument, for finding the Latitude when the Sun might be seen; but the Horizon was obscured by a Fog, I tried many ways, some of which answered pretty well; but that which I found to come nearest the Truth, was a Contrivance  
which



which I adapted, with Mr. *Bird's* Leave, to his Quadrant, which upon great Numbers of Trials, made by many others as well as myself, always determines the Latitude (without using the Horizon) to the Nearness of 5 or 6 Minutes: And now that I have mentioned Mr. *Bird*, I must do him the Justice to say, that his Instruments for Neatness and Accuracy, do in my Opinion come up to, if not exceed any I have seen or used, nor do I mean this to the Prejudice of any other Workman; how far I am just, will appear to whoever has seen the curious Astronomical Quadrant, and other Instruments done by him, for the Royal Observatory at *Greenwich*.

There is another kind of Sea Quadrant executed by Mr. *Cole*, which seems an Improvement of *Davis's*, and may possibly be more exact; but as I never had an Opportunity of trying it at Sea, I cannot pretend to judge of its Goodness.

As for the Fore-Staff, Nocturnal, &c. they are deservedly laid aside, by all who would use good Sea Instruments.

Mr. *Harris* indeed, in that excellent Book of Navigation, he published about 20 Years ago, describes a very ingenious kind of Fore-Staff for measuring Altitudes at Sea, when they do not exceed 40 Degrees, and which from its Construction must be much more Accurate than the other; but I believe then, *Hadley's*

Quadrant was either not known, or but little used.

The same Gentleman, has in his Treatise just mentioned, took Notice of a great many Errors committed in Reckonings at Sea, some of which he has with equal Judgment and Clearness shewn to arise from a false Theory, while others are owing to the Use of inaccurate Instruments, and the mistaken Notion, that the Conclusions drawn from Observations made with them, are nearer Truth than they possibly can be.

To the Instruments used at Sea, it may not be improper to add the usual Charts and Tables, as they are indeed a kind of Instruments.

It has been already shewn in this Essay, that Mr. *Wright's* Projection (erroneously called *Mercator's*) is much the most proper for all the Purposes of Navigation, and nearer the Truth than any other: As to what difference there has been found, (by some curious Observations of late Years) between the Equatorial and Polar Diameters of the Earth, it is so very small, as to have no sensible Effect in Navigation; in which we still suppose the Land and Water to have a spherical Figure: And it seems not worth while to use a Table of Meridional Parts computed from the Hypothesis of the Earth's being an Oblate Spheroid, as the longer Diameter is found to exceed the shorter, by only about 32 Miles.

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The Difference of Latitude, and Departure to each Distance and Course (after Allowance has been made for the Needle's Variation, the Leeway, and Current when there is any) is usually taken from a Table computed for that purpose to every Point, quarter Point, and Degree of the Quadrant; and if this Table is correct, these Things thence found, and regularly transferred to the Traverse Table, will give the Difference of Latitude, Departure, Course and Distance made good upon a whole Day's Run exact enough; which are Data sufficient from whence to find the Difference of Longitude: But I cannot help preferring the *French* Method of working their Traverses by a Sinical Quadrant, which will give these Things near enough the Truth, and with this Advantage besides; that as in this Way, every one of the Quantities given or sought, appears in its real, or at least, proportional Magnitude, the Idea upon the whole must be more distinct; and the Error of transferring one or more Figures wrong from the Table, or mistaking one Figure for another (Things that frequently happen) will here be avoided.

Mr. Cole, the Instrument-maker, in *Fleet-street*, has lately shewn me a Quadrant, which I take to be as exact as the Sinical Quadrant; and as it is much more Simple, must also be attended with less Error in Practice; such a Contrivance I once at Sea executed, and found it answer the Purpose of determining



mining the Course, Distance, Difference of Latitude and Departure, from the proper Data, with as great Accuracy, and a less Chance of Error than the common Tables, and as such I beg Leave from my own Experience to recommend it to every ingenious Seamen.

And as the Method of finding the same Things by *Gunter's* Scale is very easy and expeditious, if not equally exact with the others, it will at least serve as a good Check, and discover every Error of any Consequence that may have crept in; and as such, I would beg Leave to recommend the frequent Use of it.

To a Man that would keep a good Reckoning, it must be a Satisfaction to know, that he has truly deduced his daily Difference of Longitude from the proper Data; and as nothing can be a better Check upon his Computation of it, than a well divided *Wright's* Chart, he will, by pricking off the Ship's Place every Day, not only acquire a truer Notion of her successive Change of Place, but also have it in his Power to discover, whether he has err'd in computing her Place upon the Surface of the wide extended Ocean: I dare say, whoever considers these Advantages, will be induced to make use of this valuable Chart; but the Misfortune is, that few would be at the Pains to divide a Chart of this kind as it ought, nor indeed is it well practicable on board a Ship, where the Instruments requisite to divide it accurately, are seldom to be had; therefore

therefore, that every one who will use so necessary a Check, may, with little Trouble, and at a small Expence, have it ; I intend soon to publish a Set of them, carefully divided from a convenient Scale, and to have as many cast off from the Copper-Plate as may be wanted.

Most Books of Navigation have the necessary Tables, but in a great many of them they are very incorrect, and as the Proportions work'd from these must of consequence be erroneous, it were to be wish'd, we had an Edition in which great Care had been taken to have the Numbers correct, printed with a clean Figure, on a strong good Paper, and of a convenient Size : As I am apt to think, that none who know the Value of correct Tables at Sea, would grudge bestowing a few Shillings upon such a compleat Set, I have a Design to publish one, a Copy of which any Person shall have *gratis*, if he discovers one material Error in it.

The Rules and Directions commonly given by the Writers of Navigation, for guessing at the Place of a Ship, when the observed Latitude differs from the Latitude by Account, seem to be pretty reasonable ; only it is pity that none of them can be apply'd in the Case, when a Ship's Course has been nearly that of four Points from the Meridian ; nor can I see any better Way left for making a tolerable Judgment in a Case of this Nature, than using the best Means we can to discover the real Distances sail'd on each Course, and then, when  
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at Length the observed Latitude is found to differ from that by Account, to attribute this Difference to the want of due Care at the Helm, or to the unavoidable Errors of Steerage.

If indeed, there were any practicable Method shewn to discover the Longitude a Ship is in at Sea ; by that, and a good Quadrant, her Place might be truly assign'd at any Time, and the true Bearing and Distance of any Harbour or Point of Land (whose Latitude and Longitude are known) might be accurately determined.

But though this much desired and really great Improvement of Navigation, has been attempted by many, whose Qualifications might give hopes that they would have succeeded ; we find they have all in the Event been disappointed.

To me it seems evident, that all who have attempted the Discovery of this valuable Practice, have err'd in that ; either being led on by too sanguine Hopes of enjoying the great Reward offered to whoever shall be so lucky as to succeed ; they have not thoroughly weigh'd their several Schemes laid for reducing this Problem to Practice ; or have not well considered the Difficulties attending such a Discovery ; or, (which I am apt to think has been a more prevailing Error than the other two) that People who had not enough considered the Nature of the Thing, imagin'd the Invention to lye in some subtil Knack, which might be accidentally hit upon by some Man of a clear  
Head



Head, and a Mechanical Genius ; so that the Imagination being let roam at full Liberty, the first Contrivance that struck it with a favourable Aspect, was sure to meet with a kind Reception, and the Mind so intent upon viewing the Excellencies of its own Invention, could not well be supposed to spare Time to view it coolly and impartially.

But if we give ourselves the Trouble to reflect, that the Improvements already made in this, or indeed any other Art, have never been by the Lump, but gradually, and often by very small Degrees ; we must conclude with a Parity of Reason, that this so difficult in itself, and wherein so many have laboured to no Purpose (if ever it is discovered) will be promoted by slow and regular Advances, till it may possibly be brought at last to answer the Design.

It would be endless to mention the several Schemes that have been fallen upon, to make the Longitude at Sea known from Observation ; and I believe the Right Honourable the Board of Admiralty are not seldom, nor a little teased by our Longitude Finders ; but it is certain, that if the Variation of the Compass were observed with great Care through the whole Course of most Voyages, and these several Variations of the Needle properly register'd, with the Latitude well determin'd from Observation, and the Longitude as well as it could be guess'd at, in which each Variation was observed, this would be one very good Step towards coming  
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somewhat near finding the Longitude from Observation.

For in any following Voyage, at no great Interval of Time, wherever any one of these Variations well observed were found; the Longitude corresponding to that Variation, would soon appear from the Register I have supposed to be kept.

A good Pendulum Clock, which is the most exact Instrument we have for measuring Time, cannot be used at Sea, on account of the Ship's Motion; and as to Watches, or indeed any other Movements for this Purpose, they are in general liable to so many Irregularities from Heat and Cold, and perhaps the State of the Atmosphere, that the best of them will not measure Time, near the Truth.

Mr. *Harrison's* Clocks, undoubtedly bid fairest for measuring Time truly at Sea, of all that ever were invented for that Purpose; and his unwearied Pains to bring his curious Machines to still greater Degrees of Exactness, will in Process of Time (we hope) have the desired Effect. But granting we had a just Measure of Time at Sea, there is still requisite a good Method of finding the apparent Time, in that Place where the Ship is; as it is from comparing the true and apparent Time that the Difference of Longitude must be had; and I must frankly acknowledge, that I know of no Method by which to determine the apparent Time at Sea, with less Error than that of some  
Minutes

Minutes, which if we take to be only five, this Error, when reduced to its proportional Part of the Equator, will amount to no less than 75 Sea-Miles: It is true, the same Error in Time will have a less Effect in high Latitudes, not that it will occasion a less Error in Difference of Longitude; but for this Reason, that an Error of 75 Minutes of Longitude at the Parallel (suppose) of 60 Degrees, does not exceed one Half of 75 Sea-Miles, that is 37 and a Half.

Having now made almost an End of what I proposed to write on this Subject, and what I call New in it, is at least so to me; I shall venture to make some Observations which perhaps may seem worthy the Perusal of a curious and candid Reader; not that I would presume to assert from Experiment, that every thing will be found to answer as I have apprehended, but in Effect, if the Hints given may be useful any how, I have my Aim.

Of all the various Methods which have been thought of, for to know the Difference of Longitude a Ship makes at Sea, from her several Motions (whether guided by Design or Chance) the observing of the Eclipses of *Jupiter's* Satellites (or Moons) seems to bid much the fairest, were it practicable, in spite of the Rolling and other Motions of the Ship: But as I believe that no Art has yet appeared, by which a Telescope of a sufficient magnifying Power, can be kept steady enough at Sea for making  
such



such Observations ; of course the Use of a good Glass there, is extremely little, or next to none at all ; and though I cannot say whether this valuable Instrument, after all the Improvements it has had of late, (chiefly from Mr. *Short*) may ever be brought to answer the great Purpose just mentioned ; yet, if it can be used, even to discover with more Certainty, what Objects present themselves at no greater Distance than the Verge of the visible Horizon ; even this, I say, is not seldom of very great Moment at Sea.

Under the necessary Limitation then, which I have lately mentioned ; let us imagine a Person who has been used to the Management of a good Telescope, of the reflecting Kind, a-shore, to be situated so in a Ship, that like a Compass which is well hung, he may not be affected with a great deal of the Ship's Rolling, or other Motion, and we shall allow that this cannot be less than to throw his Eye off, perhaps five Degrees on one Side or other of an Object it was pointed upon ; from this Supposition, the Effect of the Ship's Rolling will be, that his Eye will be the Vertex of a sort of Cone, whose Angle at the Eye will not exceed ten Degrees, and the Circumference of whose Base the Object will seem to describe. Now if the Telescope could take in a Field of about ten Degrees, it is plain that the Observer might always keep the Object in View ; but as I believe no good Glass can take in so much, and at the same Time be distinct ; let us try to lessen still farther the Effect of the Ship's Motion ; thus,

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A reflecting Telescope of about 6 Inches of Mr. *Short's* making, will very distinctly discover *Jupiter's* Moons ; imagine such a small one properly fixed to something in form of a leather Cap, the Eye-piece so near the Eye as may be most convenient, and a Finder to collimate nearly with the Telescope ; and at such a Distance, that when the Glass is thrown off the Object, the other Eye by means of the Finder may readily bring it back into the Field of View ; and let this Cap or Head-piece be so made as to be easily fastened to the Observer's Head ; then has Nature provided us with a curious Apparatus for the Management of the Telescope, I mean the Capacity every Man in Health will find he has, of moving his Head to a great Nicety, so as with his Eye, to trace the real or apparent Motion of any Object.

In this Manner one would be led to think, that if the Observer could not keep a constant View of the Planet and his Moons, he might at least have them in the Telescope as often as the Ship came to be a little more steady, which she will often, as one Sea has lost its Effect upon her Rolling, till another meets her. If, in fact, by this Means a distinct Sight of the Planet and his Moons can be had once or twice in a Minute of Time, I am well assured that no Man whose Fortune and Leisure would incline him to try the Experiment, would have any Reason to repent his well intended Labour : For my Part, Fortune is not so friendly as to  
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put it in my Power to try that, and many other Things, which seem in my Opinion likely to increase the useful Knowledge of Mankind.

This last described Proposal for rendering the reflecting Telescope useful at Sea, was thought of by a very ingenious Gentleman, now dead, I mean Mr. *Richard Graham*, but whether before or after I hit upon it, is what I cannot with certainty determine; only this I know, that in Conversation with him some Years ago, I hinted at such a Thing as useful, if practicable; and he agreed with me in thinking it was: It is probable, this Gentleman might have thought of the very same Contrivance with me, and possibly about the same Time too; and therefore I would no farther pretend to claim the Invention, than seems to every impartial Reader consistent with strict Justice; nor indeed can its Value, but from frequent and good Trials be ascertained.

If upon the whole this first Essay is found to be really what it was intended, an Improvement, I shall have in a great Measure my Aim; though I will not be so inconsistent with the Truth as to deny, that I could heartily wish the public Good, and my private Interest were at no Variance; and, if this does not seem so modest, I am sure it is true. Neither have I ventured to let it make its Appearance to the World, before I was well assured it had undergone the Perusal of such, whose Judgment seemed to me, and I believe is, in fact, preferable by great odds to mine.

Before



Before I conclude this Essay, I must beg Leave to inform the Public, that I am fully satisfied that Mr. *Morgan*, in *Finch-lane*, near the *Royal Exchange*, makes with Neatness and Accuracy, all kinds of Mathematical Instruments; and as I have an Intention to employ him to make those described in this Essay, I only do him justice, when I say, that such may be had of him as may be depended on.

F I N I S.





